Experimental Characterization of the Mechanical Behaviour of Adobe Bricks of Existing Constructions in Aveiro District

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Abstract. A significant number of existing adobe constructions in Aveiro district presents pronounced structural degradation, which results, in great part, from the lack of sensibility for the preservation of this patrimony, and also from the shortage of knowledge concerning the behaviour of the applied materials. An important difficulty for the technicians working in the rehabilitation of this type of buildings lays indeed in the scarcity of knowledge on the mechanical behaviour of adobe units and adobe walls.

The mechanical properties of adobes taken from houses and land dividing walls, representative of the construction in Aveiro district, were investigated. Cylindrical specimens extracted from the collected adobe samples were subjected to compression and splitting tests.

This article describes the tests that were carried out and presents the obtained results, discussing them. The achieved results will support the behaviour characterization of existing structures, and help in the calibration of numerical models for the simulation of the adobe constructions behaviour.

Introduction

In the near past, earth was a very common construction material in Portugal. Adobe and rammed earth were used through years in almost all types of construction, having this utilization declined during the first half of 20th century, with the emergence of cement industry. Rammed earth was more applied in south and adobe in littoral center, especially in Aveiro district [1,2]. Presently, according to information from the municipality, about 25% of the existing buildings in Aveiro city are made of adobe. It is estimated that this percentage rises to 40% when referred to the entire district, reflecting the importance of this construction system in rural areas. Adobe can be found in varied types of construction: rural and urban buildings, many of which are still inhabited, walls for the delimitation of properties, water wells, churches and warehouses (Fig. 1). An important number of the urban adobe buildings are of cultural, historical and architectonic recognized value, belonging some of them to the "Art Nouveau" style. A more detailed description of the predominant constructive typologies can be found in [3].

The techniques adopted in the construction of adobe buildings in Aveiro district were based in the accumulated experience, transmitted from generation to generation, and did not concern the seismic safety. Rehabilitation and strengthening of existing adobe constructions have also been disregarded during decades. This constructed park is thus not properly reinforced to resist to seismic actions, suffering of various structural anomalies and deficiencies. Structural rehabilitation of the existing adobe constructions is demanded, and constitutes an urgent matter. It presents, however, relevant difficulties, essentially due to the lack of information concerning properties and characteristics of the mechanical behaviour of adobe masonry. Technical studies for the

determination of these properties and characteristics are necessary. The mechanical characterization of adobe existing masonry constitutes a fundamental instrument in the support of rehabilitation and strengthening projects, and even in the support of the design of new adobe constructions [4].

Figure 1: Examples of existing adobe constructions in Aveiro district.

Mechanical Characterization of Adobe Units

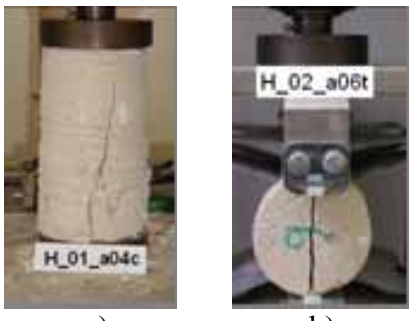
Introduction. A research group of the Civil Engineering Department, from the University of Aveiro, has been developing studies and experimental tests to aid filling the technical information gap concerning the structural behaviour of existing adobe constructions.

For the investigation of the structural behaviour and the strength and stiffness characteristics of masonry, the study of the mechanical behaviour of its constituent materials is fundamental. The mechanical characteristics of adobe units taken from houses and land dividing walls, considered representative of the construction in Aveiro district, were thus investigated. Cylindrical adobe specimens cores were subjected to compression and splitting tests. These tests allow the evaluation of the strength capacity of these materials, but also the stiffness and deformation evolution for increasing loading.

Selection, Preparation and Testing of the Adobe Specimens. In Aveiro district, adobe units present a large variability in what concerns to dimensions and constitution. Mechanical properties of adobe are therefore characterized by a significant heterogeneity. For the experimental testing campaign, it was selected a set of samples representative of different existing adobe construction typologies. Samples were collected from eight houses and eight land dividing walls, from different locations, in order to adequately characterize the mechanical behaviour of the material. Samples were constituted, whenever possible, by entire adobe blocks, and a minimum of three samples by construction for each type of test was collected.

Cylindrical cores, with diameters ranging between 60 and 95mm, were extracted from the collected adobe samples units. These cylindrical cores had a height of approximately two times the diameter.

A total of 101 cylindrical specimens, 51 proceeding from houses and 50 from land dividing walls, were submitted to mechanical tests: 83 specimens were submitted to compression; and 18 to splitting tests (Fig. 2).



a) b)

Figure 2: a) Simple compression and b) splitting tests on adobe specimens.

Results Analysis and Interpretation. Compressive strength and tensile strength of adobe units were obtained from simple compression and splitting tests, respectively. The unconfined compressive strength is given by Eq. 1:

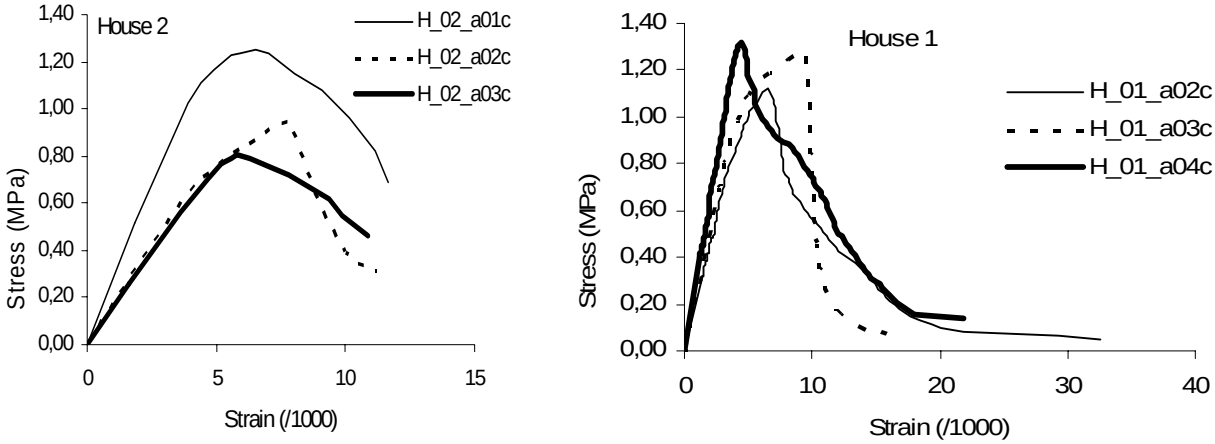
$$f_c = k_a F_c / A. \quad (1)$$

where k_a is the aspect ratio factor (calculated according to [5]); F_c is the failure load; and A is the compressed cross-sectional area. The tensile strength, as described in [6], is given by Eq. 2:

$$f_t = 2F_t / (\pi DH). \quad (2)$$

where F_t is the failure load; D and H are the diameter and the height of the specimen, respectively.

It was also obtained for each tested specimen, from the stress-strain behaviour curves (Fig. 3), an estimative of the elasticity modulus (E) and of the strain at peak strength (ε_p).



a) b)

Figure 3: Stress vs. strain relations obtained in a) simple compression and b) splitting tests.

From the adobe specimens collected from existing constructions in Aveiro it was observed a significant compressive strength. The average unconfined compressive strength, calculated per construction, ranges between 0.53MPa and 1.72MPa. For each analysed construction, the tensile strength corresponds to approximately 20% of the corresponding unconfined compressive strength (Fig. 4).

The compressive strength obtained for the tested adobe samples is, in a general way, inferior to the minimum values imposed in standards [5,7,8,9]. It should be noted that the cited standards concern new constructions while the analyzed materials were taken from old adobe constructions, many of which are considerably degraded. However, the adobe units' strength evaluation provides reference values for the structural safety assessment of existing constructions and for the identification and quantification of eventual strengthening needs.

The average strain at peak strength, calculated per construction, ranges between 6‰ and 14‰, with exception of house 4, which equals 28.0‰. The average modulus of elasticity, calculated per construction, assumes values in a large range, between 51MPa and 448MPa. According to [10], the studied adobe can be classified as a silty or poorly graded material, as the obtained modulus of elasticity values is in the range between 120kPa and 3GPa.

Linear correlations (best-fit) between the analyzed mechanical parameters were studied and are plotted in Fig. 4 and Fig. 5.

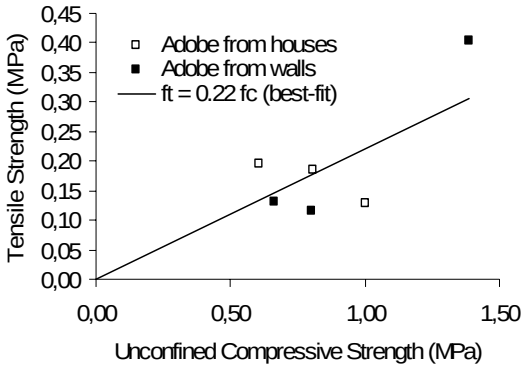


Figure 4: Tensile strength vs. unconfined compressive strength correlation, for adobe specimens.

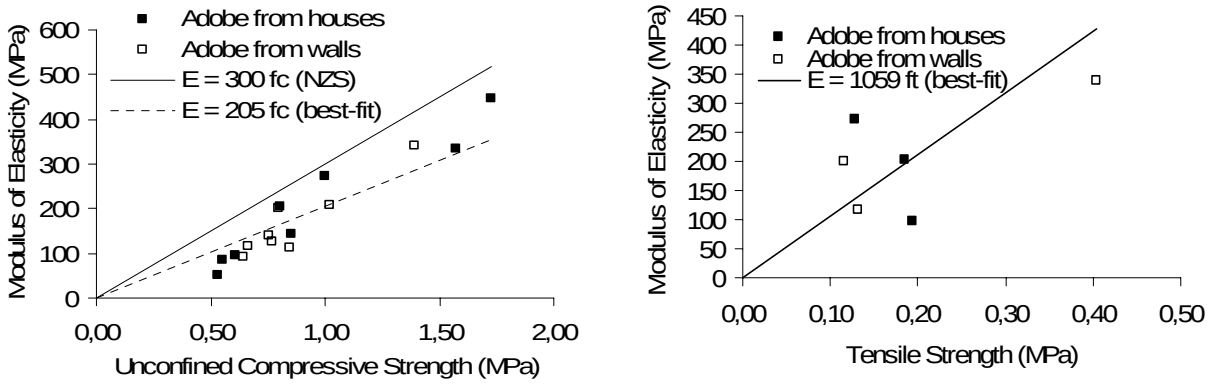


Figure 5: a) Modulus of elasticity vs. unconfined compressive strength correlation, for adobe specimens. b) Modulus of elasticity vs. tensile strength correlation, for adobe specimens.

A significant difference between the mechanical properties obtained for each construction was verified. In a general way, for each construction, the test results variability obtained is also high. Land dividing walls present, normally, a larger variability of its mechanical properties than houses. The verified results variation, even for the same construction, is justified in one way by the material heterogeneity, but also by the production and curing adobe procedures.

Work in Development

A group at the Civil Engineering Department from the University of Aveiro has been developing research work focused in the rehabilitation and strengthening of the adobe constructed park of Aveiro district [11,12,13,14]. The following methodology is being followed: i) detailed survey of the existing constructions and of the commonest structural and non-structural pathologies; ii) material mechanical characterization; iii) structural characterization and evaluation of structural safety; iv) development of non-structural rehabilitation and structural strengthening solutions. Part of the work developed was presented in this paper.

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